

reasons may be related to the vulnerability of juveniles as discussed above.

To insure success with transplanting techniques, it is essential to reduce mortality among transplanted clams either by protecting them from significant sources of mortality in the field or by retaining them in protective "nurseries" until they pass this critical phase. Past attempts to protect juveniles in the field by building fences to exclude predators have proven costly, difficult to carry out, and unreliable (Smith et al. 1955). More promising are recent advances in aquaculture techniques for commercially important bivalves. By employing "nurseries" for the young and field "grow-out" procedures for adults, sources of juvenile mortality can be reduced while still utilizing natural sources of food during the greater part of the individual's growth period.

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#### THE OCCURRENCE OF PISCINE ERYTHROCYTIC NECROSIS (PEN) IN THE SEA LAMPREY, *PETROMYZON MARINUS*, FROM SEVERAL MAINE LOCALITIES

The sea lamprey, *Petromyzon marinus*, is an anadromous fish found in the North Atlantic Ocean from Iceland and northern Europe to northwestern Africa, and from the Grand Banks and the Gulf of St. Lawrence to Florida (Hubbs and Lagler 1949). The sea lamprey has adopted an entirely freshwater life cycle in the Great Lakes where it has seriously depleted fish populations (Everhart 1976).

The lamprey feeds on other fishes by hanging on with its sucking mouth. Once attached, it

rasps its victim with its tongue to obtain nourishment in the form of blood and other body fluids (Everhart 1976). Secretions from a pair of relatively large salivary glands below the tongue retard coagulation of host blood and also dissolve tissue (Lagler et al. 1977). Bigelow and Schroeder (1953) reported that in saltwater, lampreys have been found preying on mackerel, shad, cod, haddock, pollock, salmon, basking sharks, various anadromous herrings, swordfish, hake, sturgeons, and eels.

Piscine erythrocytic necrosis (PEN), a condition characterized by cytoplasmic inclusions and nuclear abnormalities in erythrocytes, has been shown to be of viral etiology in the Atlantic cod, *Gadus morhua*, and Atlantic herring, *Clupea harengus harengus*, from the Atlantic coast and the chum salmon, *Oncorhynchus keta*, pink salmon, *O. gorbuscha*, and Pacific herring, *Clupea harengus pallasi*, from the Pacific coast of North America (Walker 1971; Appy et al. 1976; Walker and Sherburne 1977; Philippon et al. 1977; Reno et al. 1978; Evelyn and Traxler 1978; MacMillan and Mulcahy 1979). In addition, PEN has been reported in 15 other marine teleost species from the Atlantic coast of North America, but confirmation as to viral etiology has not been made (Laird and Bullock 1969; Walker and Sherburne 1977; Sherburne 1977; Sherburne and Bean 1979). PEN has also been evident in the Atlantic mackerel, *Scomber scombrus*, (Sherburne, unpubl. data).

This report documents the first finding of PEN in a host from the most primitive group of fishes, the Agnatha.

## Materials and Methods

A total of 142 lampreys, *Petromyzon marinus*, was obtained for blood analysis from 5 Maine localities (Table 1). Live lampreys were measured for total length and sexed. Slides were prepared by severing the caudal peduncle and taking the blood into a heparinized capillary tube, from which a small drop of blood was placed on a microscope slide and the smear made. Air-dried smears were Giemsa-stained and thoroughly examined for PEN using light microscopy at 1000× magnification.

## Results

Of the total lampreys sampled in this study, 50.7% (72/142) had red cell lesions characteristic of PEN (Table 1). By light microscopy, PEN lesions of lamprey red cells often showed the nuclear chromatin condensed into round blebs, and there was evidence of nuclear vacuolization (Fig. 1). Red acidophilic cytoplasmic inclusions were occasionally seen in an infected cell (Fig. 2).

Individual infections were light, with only one or two infected cells evident in most smears. Among the 72 infected lampreys, the severest infection involved 2% of the red cells and it occurred in a 69 cm male from the Coopers Mills Fishway on 26 May 1980.

From a total of 139 lampreys sexed, 47.9% of the males and 53.0% of the females had PEN. The smallest infected lamprey was 62.4 cm (24.6 in) long; the largest was 81.5 cm (32.1 in).

TABLE 1.—The occurrence of piscine erythrocytic necrosis (PEN) in the sea lamprey, *Petromyzon marinus*, from several Maine localities.

| Sample source          | Location      | Date         | PEN                 |                   | Mean length, SD, and range (cm) of sample |
|------------------------|---------------|--------------|---------------------|-------------------|---|
|                        |               |              | Incidence in sample | Percent incidence |   |
| Nequasset Lake Fishway | Woolwich      | 16 June 1977 | 0/2                 | 0.0               | 67.0 ± 1.4 (66.0 – 68.0)                  |
| Kennebunk River        | Kennebunk     | 11 May 1978  | 1/1                 | 100               | 63.1 (63.1)                               |
| Sheepscot Pond Fishway | Palermo       | 9 June 1978  | 1/3                 | 33.3              | 65.4 ± 2.7 (62.5 – 67.8)                  |
| Sheepscot Pond Fishway | Palermo       | 15 June 1978 | 0/1                 | 0.0               | 65 (65)                                   |
| Sheepscot River        | Coopers Mills | 30 May 1979  | 5/28                | 17.8              | 72.4 ± 4.1 (62.4 – 82)                    |
| Coopers Mills Fishway  |               |              |                     |                   |   |
| Sheepscot River        | Coopers Mills | 26 May 1980  | 34/46               | 73.9              | 72.4 ± 4.6 (66 – 88.5)                    |
| Coopers Mills Fishway  |               |              |                     |                   |   |
| Sheepscot River        | Alna          | 6 June 1983  | 7/18                | 38.8              | 71.4 ± 4.3 (64.8 – 78.8)                  |
| Head Tide              |               |              |                     |                   |   |
| Sheepscot River        | Coopers Mills | 13 June 1983 | 1/4                 | 25.0              | 73.5 ± 2.3 (70.0 – 75.0)                  |
| Coopers Mills Fishway  |               |              |                     |                   |   |
| Sheepscot River        | Alna          | 14 June 1983 | 5/8                 | 62.5              | 70.6 ± 3.4 (66.7 – 76.0)                  |
| Head Tide              |               |              |                     |                   |   |
| Sheepscot River        | Alna          | 15 June 1983 | 18/31               | 58.1              | 70.5 ± 4.0 (63.5 – 78.0)                  |
| Head Tide              |               |              |                     |                   |   |

FIGURE 1.—Sea lamprey erythrocytes with PEN lesions. Infected cells show characteristic chromatin condensation with evidence of nuclear vacuolization. From a female lamprey 80 cm in total length from the Coopers Mills Fishway, Coopers Mills, Me., on 26 May 1980. Sea lamprey erythrocytes are rounded in shape in contrast to most other fish species which have elliptical shaped red cells.

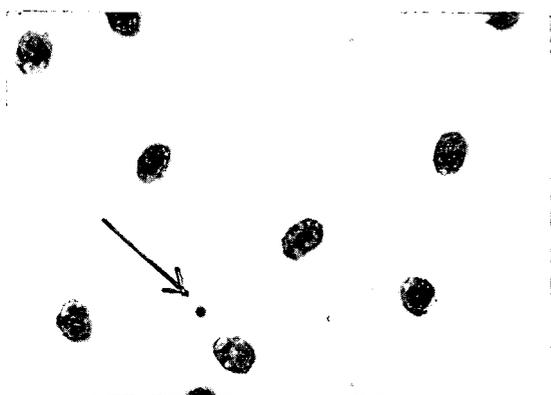
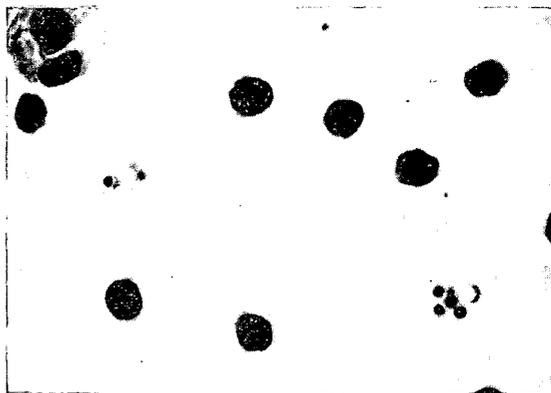


FIGURE 2.—Red acidophilic inclusions are occasionally seen in PEN infected sea lamprey erythrocytes. From a female lamprey 67.8 cm in total length from the Sheepscot Pond Fishway, Palermo, Me., on 9 June 1978.

#### Discussion

I prefer to use the term PEN in species where the cellular pathology has not yet been confirmed as associated with a virus, and viral erythrocytic necrosis (VEN) after confirmation. By light microscopy, PEN lesions of lamprey red cells resemble those of VEN-infected Atlantic cod. As with alewives, *Alosa pseudoharengus*, (Sherburne 1977) and smelt, *Osmerus mordax*, (Sherburne and Bean 1979), lampreys have a relatively high percentage of individuals affected with PEN, but individual infections are very light.

The blood of the sea lamprey must be examined by electron microscopy to determine if the PEN seen is an ICDV infection. Unfortunately, the individual infections observed in this study were so light as to preclude their detection by electron

microscopy. Consequently, viral etiology of the condition still remains to be confirmed.

Fish obtained from lakes where alewives spawn have shown typical PEN lesions (Sherburne, unpubl. data), but whether alewives contribute to this is unknown. MacMillan and Mulcahy (1979) reported transferring VEN to chum salmon, *Oncorhynchus keta*, and brook trout, *Salvelinus fontinalis*, by waterborne virus. Perhaps infected anadromous species can transmit PEN to freshwater species via body fluids such as urine and reproductive products as well as by direct contact.

Lampreys could conceivably transmit PEN to a variety of marine and freshwater species because of their feeding habits, their diversity of prey, and their ability to become adapted to an entirely freshwater environment. The high prevalence of infection and the low intensity of infection suggest that lampreys might readily spread the infection without suffering a high mortality rate from PEN.

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